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Wear compliance, sedentary behaviour and activity in free-living children from hip-and wrist-mounted ActiGraph GT3X+ accelerometers

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Abstract

This study examined the compliance of children wearing wrist- and hip-mounted ActiGraph GT3X+ accelerometers and compared estimates of sedentary behaviour (SB) and physical activity (PA) between devices.

One hundred and eighty-eight 9-12-year-old children wore a wrist- and hip-mounted accelerometer for 7 days. Data were available for 160 (hip) and 161 (wrist) participants. Time spent in SB and PA was calculated using R-package GGIR.

Wear-time for the wrist (15.6 to 17.4 $h.d^{-1}$) was significantly greater than the hip (15.2 to 16.8 $h.d^{-1}$) across several wear-time criteria (all P<0.05). Moderate-strong associations were found between time spent in SB (r = 0.39), LPA (r = 0.33), MPA (r = 0.99), VPA (r = 0.82) and MVPA (r = 0.81) between the two device placements (All P < 0.001). The wrist device detected more minutes in LPA, MPA, VPA and MVPA whereas the hip detected more minutes in SB (all P = 0.001). Estimates of time in SB and all activity outcomes from the wrist and hip lacked equivalence.

The GT3X+ when worn at the wrist promotes greater compliance than at the hip. Minutes in SB and PA calculated from raw accelerations at the hip and wrist provide contrasting estimates and cannot be directly compared.

Key Words: physical activity, ActiGraph GT3X+, wear time, raw acceleration.

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Authors' Contributions:

GMcL collected all of the data, performed the statistical analysis and drafted the manuscript; RA and DSB conceived, designed and coordinated the study, assisted with the statistical analysis and helped to draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of authors.

None of the authors declare competing financial interests.

Conflicts of interest: none.

Introduction

Accelerometers are widely used to capture children's free-living physical activity (PA) (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013) that can provide valid and reliable estimates of children's PA at varying intensities (Butte, Ekelund, & Westerterp, 2012). Of the many different types of accelerometers available (Actical, Actiwatch, GENEActiv, Axiivity, etc), the ActiGraph (Pensacola, FL, USA) accelerometers are one of the most commonly used by researchers owing to the large body of evidence supporting its use (Cain et al., 2013). These small (5.08cm x 4.06cm x 1.52cm), lightweight (42.52g) devices have typically been attached to the hip in order to reflect both the quantity and quality of whole body movement and thus energy expenditure (Rowlands et al., 2014). However, when worn at the hip, wear time compliance is often poor which can result in a sizeable loss of data (Cain et al., 2013). Moreover, poor wear time compliance can lead to selection bias and misclassification (Rowlands et al., 2014).

With these concerns and the association between duration of monitoring and the reliability of PA data (Banda et al., 2016), there has been increased interest in the use of wrist-mounted monitors to assess habitual PA (Fairclough et al., 2016; Li, Kearney, Keane, Harrington, & Fitzgerald, 2017; Noonan, Boddy, Kim, Knowles, & Fairclough, 2017; Rowlands et al., 2014; Scott et al., 2017). An important technological advancement in accelerometry has been the ability to access the triaxial raw acceleration data prior to being processed, filtered and scaled from devices such as the ActiGraph GT3X+ and GENEActiv (ActivInsights Ltd., Cambridge, UK). This move toward raw data processing had been recommended by a panel of experts in 2009 (Freedson, Bowles, Troiano, & Haskell, 2012) to overcome the limitations associated with traditional count-based approach's to estimate PA and sedentary behaviour (SB) (Cain et al., 2013). With such an approach, there is an opportunity to enhance the comparability between studies using different accelerometers as well as affording greater transparency and consistency of post-data processing methodologies (Fairclough et al., 2016; Hildebrand, Van Hees, Hansen, & Ekelund, 2014). Nonetheless, with the use of wrist-mounted accelerometers it is important to establish whether PA and SB outcomes are comparable to that derived from hip- mounted devices, and whether wear-time compliance is enhanced for children under free living conditions.

Recently, Fairclough and colleagues examined compliance to wearing wrist- and hip- mounted accelerometers during free living in 9-10 year olds (Fairclough et al., 2016) and found that more children wore the accelerometer at the wrist than the hip, regardless of wear-time criteria applied. Similarly, Noonan and colleagues reported more children adhering to a 3 day (including 1 weekend day), 10 hour or more wear-time criteria when wearing wrist-mounted rather than hip-mounted accelerometers (Noonan et al., 2017). In an older sample of 13-14 year olds from Australia, Scott and colleagues also found that wear-time compliance was significantly higher with wrist- rather than hip- mounted accelerometers and found that the wrist- mounted accelerometer had 50% fewer non-valid days (75 days, 12%) than the hip- mounted accelerometer (n =152, 24.4%) (Scott et al., 2017). Furthermore, participants found the wrist- mounted accelerometer more comfortable and less embarrassing to wear than the hip-mounted accelerometer, which has been cited as a key determinant of accelerometer wear time (Scott et al., 2017). However, as these studies all used the wrist-mounted, watch-like GENEActive (Fairclough et al., 2016; Noonan et al., 2017; Rowlands et al., 2014; Scott et al., 2017), it is unclear whether similar compliance rates would be evident with the wrist-mounted ActiGraph GT3X+. To the best of our knowledge, only one study has reported wear time compliance rates from participants wearing the wrist- mounted ActiGraph GT3X+ in isolation over a 7-day monitoring period (Kim et al., 2017). Here the authors reported an average daily wear-time of 15.5 $h.d^{-1}$ from 12-17 year olds. Whether similar wear-time compliance rates would be evident in younger children when asked to wear two devices in parallel is unclear.

Although some work has examined the comparability of children's PA derived from raw acceleration signals of wrist- and hip- mounted devices (Fairclough et al., 2016; Hildebrand et al., 2014; Noonan et al., 2017; Rowlands et al., 2014; Scott et al., 2017), these studies have compared the comparability of outputs between a wrist- mounted GENEActive to that of a hip- mounted ActiGraph GT3X+. Findings from these studies advise caution when comparing measures of PA derived from different wear sites as the different PA outcomes are likely attributable to a decoupling effect (Fairclough et al., 2016; Noonan et al., 2017; Rowlands et al., 2014). Since different brands of accelerometers were used in these studies, it is unclear whether this decoupling effect is a result of greater accelerations captured at one placement site during certain activities or is a result of the different brands used at each placement site.

To the best of our knowledge, no study has examined the comparability of outputs between the ActiGraph GT3X+ mounted at the hip and wrist. Since the use of different device placements and accelerometer brands may result in different conclusions concerning youth activity, it is important to establish whether estimates are comparable when using raw accelerations derived from wrist- and hip- mounted accelerometers. Especially given the wealth of hip- (Cooper et al., 2015; Katzmarzyk et al., 2015) and wrist-mounted (Troiano, McClain, Brychta, & Chen, 2014)

ActiGraph accelerometer data that has been collected over the years. Thus, the aims of this study were 1) to explore the compliance of children wearing wrist- and hip-mounted ActiGraph GT3X+ accelerometers, and 2) to evaluate children's PA and sedentary behaviour from raw acceleration data provided from wrist- and hip-mounted ActiGraph GT3X+ accelerometers.

Methods

Participants

Participants were 188 children (102 girls) aged 9-12 yr old from years 5-7 attending three primary schools in South Lanarkshire, Scotland. Upon receipt of approval (ethical approval number 19-10-16-001) from the ethical committee of the University of the West of Scotland, consent forms were issued to children in years 5-7 from participating schools. The three schools were provided with 100 information packs (n=300) to be distributed to children from years 5-7. Each participant received an information pack containing an initial information letter, a medical history form and an assent form that also required parental or guardian consent. Despite 204 children agreeing to participate, 16 children were absent on the day of testing leaving a final sample of 188 children. Each participant wore two ActiGraph GT3X+ monitors, one on their non-dominant wrist and the other positioned above the right hip on a belt worn around the waist. Prior to testing, both accelerometers were synchronised with Greenwich Mean Time, initialized to capture data at 80Hz and programmed to commence data collection at 6:00am on the day following participants receiving the devices. The low frequency extension was not enabled. Verbal confirmation of participants non-dominant wrist was undertaken prior to being instructed to wear both devices. Participants were instructed to wear both devices at all times (i.e. 24 hours) for seven days, apart from water-based activities such as swimming or bathing. Participants were fitted with both accelerometers prior to leaving the testing session.

Data Management

Upon the return of both devices, data were uploaded using ActiLife v6.13.3 (Actigraph, Pensacola, FL, USA) and saved in raw format as GT3X+ files. The GT3X+ files were subsequently converted to 1 s epoch csv files containing x, y and z vectors to facilitate raw data processing. Wrist and hip data were then processed in R (http://cran.r-project.org) using the GGIR package (version 1.5-10) which allows raw accelerations (gravitational acceleration) to be processed and analysed (Van Hees et al., 2014). Briefly, the package autocalibrates the raw triaxial accelerometer signals and coverts them into one omnidirectional measure of acceleration, termed the signal vector magnitude (SVM). SVM represents the value of gravity (i.e., SVM = $\sqrt{(x^2 + y^2 + z^2)}$-1), with negative values rounded to zero. This metric has been referred to as the Euclidean Norm Minus One (ENMO) (Fairclough et al., 2016; van Hees et al., 2013). Raw data were further reduced by calculating the average SVM values per 1s epoch expressed in mg over each of the 7 monitoring days. Thereafter, raw data wear times were estimated on the basis of the SD and value range of each axis, calculated for 60 min windows with 15-min moving increments as described in detail elsewhere (van Hees et al., 2013). The default setting for nonwear was used whereby invalid data were imputed by the average at similar time points on different days of the week.

Raw accelerometer data

When comparing time spent in activity intensities from two wear locations, it is important that intensity cut-points are created from the same calibration protocol (Rowlands et al., 2014). To this end, we used the device specific prediction equations provided by Hildebrand and colleagues (Hildebrand et al., 2014) to generate intensity specific milli-g cut-points. However, these cut-points only estimate minutes of moderate (3 METs) and vigorous (6 METs) PA. Since children have higher resting metabolic rates, there has been calls for the use of standard METs (i.e. 3.5 mL/kg/min) to be adjusted since METs <2 and >4 have shown to be more accurate in classifying both sedentary behaviour and MVPA levels in children (Saint-Maurice, Kim, Welk, & Gaesser, 2015). Therefore, using the device-and location-specific Hildebrand regression equations for 2 METs and 4 METs, cut-points for sedentary behaviour (SB), light PA (LPA), moderate PA (MPA) and vigorous (VPA) were calculated. For the wrist, these were ≤32.9mg (SB), 33 - <370mg (LPA), ≥370 – <707mg (MPA) and ≥707mg (VPA), respectively. For example: mg = ((2 x 6 ml $O_2.kg^{-1}.min^{-1}$) - 10.83) / 0.0356 = 32.9mg. For the hip, these were <35.2 mg (SB), ≥35.2 - <249.9mg (LPA), ≥249.9 – <464.6mg (MPA) and ≥464.6mg (VPA), respectively. For example: mg = ((2METs x 6 ml $O_2.kg^{-1}.min^{-1}$) – 10.03) / 0.0559 = 35.2mg.

For analysis of time spent in SB and activity intensities from raw accelerations, rather than including sleep time within the analysis, data captured from 11:00pm - 6:00am were removed from both accelerometer devices. From the raw acceleration data measured at the hip, wear time was initially classified using the method described by van Hees (van Hees et al., 2013). Thereafter, plots of raw acceleration data from each participant were viewed to confirm both monitors were worn during the identified period. To address study aim 1, several wear time criteria were used in the analysis including any 3 days at 8-, 9- and 10-hours, any 4 days at 8-, 9- and 10-hours as well as any 3 days plus 1-weekend day at 8-, 9- and 10-hours. To address study aim 2, participants were required to have worn both devices on the same 4 days for a minimum of 10 hours to be included within the analysis following previous recommendations (Migueles et al., 2017; Trost, McIver, & Pate, 2005). Participants where wear time did not match or there were fewer than 10 hours of wear time for ≥4 days, were removed from the hip versus wrist raw data analyses.

Analysis

Histograms, Q-Q plots and Kolmogorov-Smirnov tests were used to examine the distribution of wear-time data for both the hip and wrist against several different wear time criteria; any 3 days at 8-, 9- and 10-hours, any 4 days at 8-, 9- and 10-hours, any 3 days plus 1-weekend day at 8-, 9- and 10-hours. Regardless of the criteria, the average wear-time data from both locations were skewed. Therefore, paired-sample McNemar tests and Wilcoxon Rank signed tests were used to assess compliance and valid mean wear time differences. Partial Pearson correlations examined the associations between the two devices for time spent in SB, LPA, MPA, VPA and moderate-vigorous PA (MVPA) whilst controlling for device wear time. As this data was skewed, all variables were transformed (square root) with the subsequent analysis performed on the transformed data. Repeated measures analyses of covariance (RMANCOVA) tests were used to evaluate differences between raw data detected from the hip and wrist devices whilst controlling for sex and device wear time. The residuals for all variables were normally distributed. The equivalence of time estimates between devices for time spent in SB and each activity was examined at the group level using the 95% paired equivalence test. To reject the null-hypothesis, the 90% confidence interval (CI) of time spent in SB and each activity estimated from the wrist had to fall within the equivalence region defined as ±10% of the mean of the hip outputs. Finally, Bland-Altman procedures (Altman & Bland, 1983) were used to assess agreement and systematic bias at the individual level between time estimates in SB and each activity derived from each monitor.

Results

Hip and wrist data were available for 160 (device malfunction n=9; device loss n=2; participant absence n=14; participant withdrawal n=3) and 161 (device malfunction n=7; device loss n=3; participant absence n=14; participant withdrawal n=3) participants, respectively. Table 1 illustrates participant compliance to different wear time criteria and by device location. Using 10 h of wear time on at least 3 days, wrist noncompliance (13%) was lower than that for the hip (18%). Regardless of device placement, the number of participants wearing both devices decreased as the minimum wear-time criteria increased. Despite more children wearing the wrist than hip devices, these differences did not reach significance across the different wear time criteria. The average daily wear-time for the hip across the different wear time criteria ranged from 15.2 to 16.8 $h.d^{-1}$ and from 15.6 to 17.4 $h.d^{-1}$ for the wrist. Moreover, daily wear time for the wrist- was significantly greater than that for the hip-device across all wear time criteria (Table 2).

A minimum of 10 h across 4 d was the chosen wear time criteria used for the subsequent analysis. This resulted in data from 102 participants being used. After controlling for device wear time and sex, moderate-strong associations were found between time spent in SB ($r = 0.39$), LPA ($r = 0.33$), MPA ($r = 0.99$), VPA ($r = 0.82$) and MVPA ($r = 0.81$) (All $P < 0.001$). Table 3 displays the comparison between time spent in SB and activity intensities from the raw accelerations generated by the hip and wrist, after adjustment for device wear-time and sex. The wrist device detected significantly more time spent in LPA, MPA, VPA and MVPA than the hip whereas the hip detected significantly more time in SB (all $P = 0.001$) than the wrist. Bland-Altman plots displayed in Figure 1A-E illustrate the degree of differences of time spent in SB, LPA, MPA, VPA and MVPA between the hip and wrist devices. The mean bias for time spent in SB and LPA were large whereas the mean bias for time spent in MPA, VPA and MVPA were small. At the individual level, limits of agreement (LoA) were wide for time spent in SB and LPA with the extent of differences for time spent in MPA, VPA and MVPA appearing to increase with children's engagement of PA. Correlation coefficients between the mean of the measures and bias were $r = -0.56$ (SB), $r = 0.35$ (LPA), $r = 0.73$ (MPA), $r = 0.81$ (VPA), and $r = 0.78$ (MVPA) suggesting that the 95% limits of agreement should be treated with caution. Finally, equivalence tests showed that hip- and wrist-derived raw estimates of time spent in SB and all activity intensities lacked equivalence.

Discussion

To our knowledge, this is the first study to directly compare ActiGraph GT3X+ compliance and time spent in SB and activity intensities derived from raw acceleration outputs from hip- and wrist- mounted accelerometers in children aged between 9-12 years. We found that more participants wore the wrist- than hip-device throughout a given week with wear-time being significantly greater for the wrist-mounted device across different wear-time criteria. This is an encouraging finding since extended wear time will provide greater confidence in the reliability of activity estimates (Aadland & Ylvisåker, 2015). Despite the lack of data examining the compliance rates of children wearing wrist- and hip-mounted accelerometers in parallel (Migueles et al., 2017), our results are broadly similar to that of others (Fairclough et al., 2016; Noonan et al., 2017; Scott et al., 2017) with more participants meeting the wear time criteria for the wrist- rather than the hip- mounted device. Although slightly different wear time criteria's were employed in this study to that of Fairclough (Fairclough et al., 2016), it is encouraging to note the similarities in average daily wear time between studies for both the wrist (15.6 to 17.4 vs. 15.6 to 15.8 $h.d^{-1}$), despite the use of different wrist-mounted accelerometers, and the hip (15.2 to 16.8 vs. 14.18 to 14.21 $h.d^{-1}$).

As in the study by Fairclough and colleagues, we required participants to wear both devices concurrently apart from water based activities. Similar requests were provided to participants in the US (Kim et al., 2017; Tudor-Locke et al., 2015). Using a wear time criteria ≥4 days with ≥10 hours per day (including 1 weekend day), Tudor-Locke and colleagues reported an average wear time for hip-worn ActiGraph GT3X+ of 22.6 $h.d^{-1}$ and a waking wear time of 14.7 $h.d^{-1}$ (Tudor-Locke et al., 2015). Using a similar wear time criteria as in this study, Kim and colleagues noted the average daily wear time to be 15.5 $h.d^{-1}$ for wrist- mounted ActiGraph GT3X+, albeit in a slightly older cohort of participants (Kim et al., 2017). These findings suggest that the wear time of GT3X+ devices worn at the wrist and hip reported in this study are broadly similar to the estimates of others who have required participants to wear either a hip- or wrist-mounted device over a 7-day period. This is encouraging since participants often cite reasons for non-compliance to accelerometer protocols because of feelings of embarrassment (Kirby et al., 2012; Scott et al., 2017) and dissatisfaction with the comfort of accelerometer devices (Scott et al., 2017). Nonetheless, further work examining the compliance of wrist worn accelerometers over a 7-day period without the need to wear a hip- mounted device is recommended to fully appreciate the combined influence of wear location and instruction upon wrist- mounted wear time compliance in children.

Regarding the second aim of our study, we observed moderate associations between wear locations for SB and LPA but strong associations for MPA, VPA and MVPA. This is the first study to report these associations between wrist-and hip- mounted GT3X+ accelerometers in children, using the device-and location-specific Hildebrand regression equations for 2 METs and 4 METs. Similar to the observations of others (Noonan et al., 2017; Rowlands et al., 2014), the lower, yet significant, associations for SB and LPA between wear locations likely reflect a decoupling of wrist and hip accelerations. For instance, hip accelerations may be higher than wrist accelerations during certain activities such as carrying bags or walking with hands in pockets where accelerations are captured at the hip but not the wrist (Rowlands et al., 2014). Alternatively, the wrist device is likely to register accelerations when seated as a consequence of writing, playing video games or fidgeting (Kumahara, Tanaka, & Schutz, 2004; Routen, Upton, Edwards, & Peters, 2012) and as data was captured during a typical school week, it is plausible that this has occurred. This too would also explain how more LPA was registered from the wrist than the hip. However, as we didn't capture children's activity modes throughout the monitoring period, it is difficult to confirm these assumptions. Where possible, future studies should consider asking participants to complete an activity mode log-book throughout the accelerometer monitoring period to confirm assumptions.

The strong associations for time spent in MVPA ($r = 0.81$) suggest that both devices measured children's free-living accelerations. In contrast to SB, we found that time spent in MPA, VPA and MVPA derived from the wrist were significantly higher than those derived from the hip, which is consistent with the findings of others (Fairclough et al., 2016; Noonan et al., 2017; Routen et al., 2012). These findings suggest that activity levels derived from the wrist and hip are heavily influenced by location. The most plausible explanation for the significant differences noted in time spent in MPA, VPA and MVPA are likely due to the decoupling effect noted above (Rowlands et al., 2014) which highlights the challenges comparing MVPA estimates between devices worn at different locations (Noonan et al., 2017).

Systematic differences in time spent in SB and activity outcomes from the wrist and hip were not observed despite time spent in SB being 21% higher from the hip compared to the wrist. Previous studies have highlighted the difficulties in capturing accurate estimates of SB from wrist accelerometers given the lack of wrist movement (Hildebrand et al., 2014; van Loo et al., 2017) although the use of one single device at the hip has also demonstrated poor accuracy when estimating total sedentary time or the number of breaks in SB (Lyden, Kozey-Keadle, Staudenmayer, & Freedson, 2012).

Time spent in LPA was found to be 78% lower from the hip when compared to that from the wrist. Similar differences were apparent for time spent in MPA (48%), VPA (50%), and MVPA (51%) with values higher for the wrist than the hip indicating a degree of proportional bias with increasing activity. Nonetheless, the magnitude of differences derived from the hip and wrist for time spent in MVPA is likely the result of minimal MVPA captured from both devices. Despite the low estimates of MVPA derived from both the wrist and hip, Kim and colleagues (Kim et al., 2017) reported similar values to those reported here using the same GGIR processing methods for wrist derived raw accelerations, with estimates ranging from

8.0 to 12.8 minutes/day. A recent study highlighted the poor classification performance of the Hildebrand thresholds for correctly classifying MVPA, primarily due to the low recognition of MPA (Trost, Rice, & Pfeiffer, 2017). Given the low MVPA values observed in this study and elsewhere (Kim et al., 2017), further calibration work may be necessary to accurately classify MPA from non-processed wrist accelerometer data using the GGIR package.

Comparing our findings to that of others is difficult since results are dependent upon selected cut-points, accelerometer brand, population used and post-processing decisions. Yet, our findings are in agreement with others who found that wrist-mounted GENEActiv had higher MVPA estimates than that derived from hip-mounted GT3X+ accelerometers (Fairclough et al., 2016; Rowlands et al., 2014). This is contrast to a recent study involving adolescents (Scott et al., 2017) which reported higher MVPA estimated during both the week and weekend for the hip-GT3X+ compared to the wrist- mounted GENEActiv. This disparity in findings highlight the need for further comparability studies examining SB and PA estimates from different wear locations and brands as well as the need for standardized hip and wrist accelerometer protocols.

Previous studies have shown that applying a population specific correction factor to wrist acceleration data can improve subsequent comparisons with hip acceleration data (Rowlands et al., 2015). This may be an appropriate method to enhance the comparability of estimates derived from different device brands and wear locations and should be encouraged in future work. Moreover, further validation work is recommended since the processing methods employed in this study have not yet been validated in an independent study, making it difficult to determine which processing technique is more accurate. For instance, the hip cut points may or may not be more accurate than those used for the wrist when estimating SB and PA.

To the best of our knowledge, this is the first study to explore the compliance of children wearing GT3X+ wrist- and hip-mounted accelerometers in parallel as well as comparing estimates of time spent in SB and PA from each location. Despite the novel findings, there are several limitations to this study. The findings from this study are based on a sample of healthy children from one location of Scotland which limits the generalisability of our findings. Device wear time was significantly greater for the wrist than the hip which may have contributed to the differences in PA outcomes between wear locations. Given the lack of sleep logs, we assumed that every participant slept between 11:00pm and 6:00am. Previous studies have also found that agreement between device locations can vary at different times of the school day (Noonan et al., 2017). Since children spend a large amount of time sitting at their desk either writing or typing on a computer during the school day, it is likely that greater accelerations were observed at the wrist than the hip during such activities. Future work should be undertaken using wrist- and hip-mounted accelerometers of the same brand to confirm the findings of Noonan and colleagues. Finally, it has been suggested that using a single regression equation to calculate intensity thresholds may not be the most accurate method to estimate time spent in different PA intensities (Lyden, Kozey, Staudenmeyer, & Freedson, 2011; Trost, Loprinzi, Moore, & Pfeiffer, 2010). It’s possible that the use of alternative methods for analysing and processing raw outputs from accelerometers (Crouter, Horton, & Bassett, 2012; Staudenmayer, Pober, Crouter, Bassett, & Freedson, 2009) may have improved the estimation of time spent in different intensities from the raw accelerations.

Notwithstanding these limitations, there are several strengths to this study. For instance, this is the first study to assess children's free-living PA derived from raw wrist and hip accelerations using the ActiGraph GT3X+ accelerometer. Estimates of SB and PA derived from raw accelerations were processed and analysed using identical, open-source procedures adding transparency and consistency to our estimates. Unlike previous work (Fairclough et al., 2016; Noonan et al., 2017; Rowlands et al., 2014; Scott et al., 2017), the use of the same accelerometer brand on both wear sites removes the influence of different brands upon the SB and PA estimates reported here. Reporting the mean difference in SB and PA intensities between wear locations is novel and has not previously been reported in children. As such, these values may be used by researchers to compare SB and PA estimates from similar populations using wrist- and hip- mounted GT3X+ accelerometers. Finally, the use of device-and location-specific cut points derived from the same validation study is a particular strength of this study.

Conclusion

In summary, wear time for the wrist was significantly greater than that for the hip across a range of different wear time criteria. This is an encouraging finding and suggests that the use of the ActiGraph GT3X+ at the wrist can encourage increased wear time which may provide a more accurate assessment of free living. Estimates of time spent in SB and PA intensities from raw accelerations between the hip- and wrist-mounted GT3X+ do not appear comparable. Further calibration work and correction factors may be necessary to facilitate the comparison of findings in studies that estimate time spent in SB and PA intensities captured from the wrist and hip.

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Table 1 The number of participants included for analysis across different wear-time criteria.

No. Hrs Per/Day	**8-Hours**			**9-Hours**			**10-Hours**		
No. Days	**3 Days**	**4 Days**	**3 Days + 1 Weekend Day**	**3 Days**	**4 Days**	**3 Days + 1 Weekend Day**	**3 Days**	**4 Days**	**3 Days + 1 Weekend Day**
Hip (n=160)	132	121	95	128	116	92	121	110	87
Wrist (n=161)	140	130	101	133	123	97	130	116	88
P	*0.092*	*0.077*	*0.286*	*0.454*	*0.210*	*0.359*	*0.077*	*0.180*	*0.999*

Table 2 Average wear time per day across different wear-time criteria.

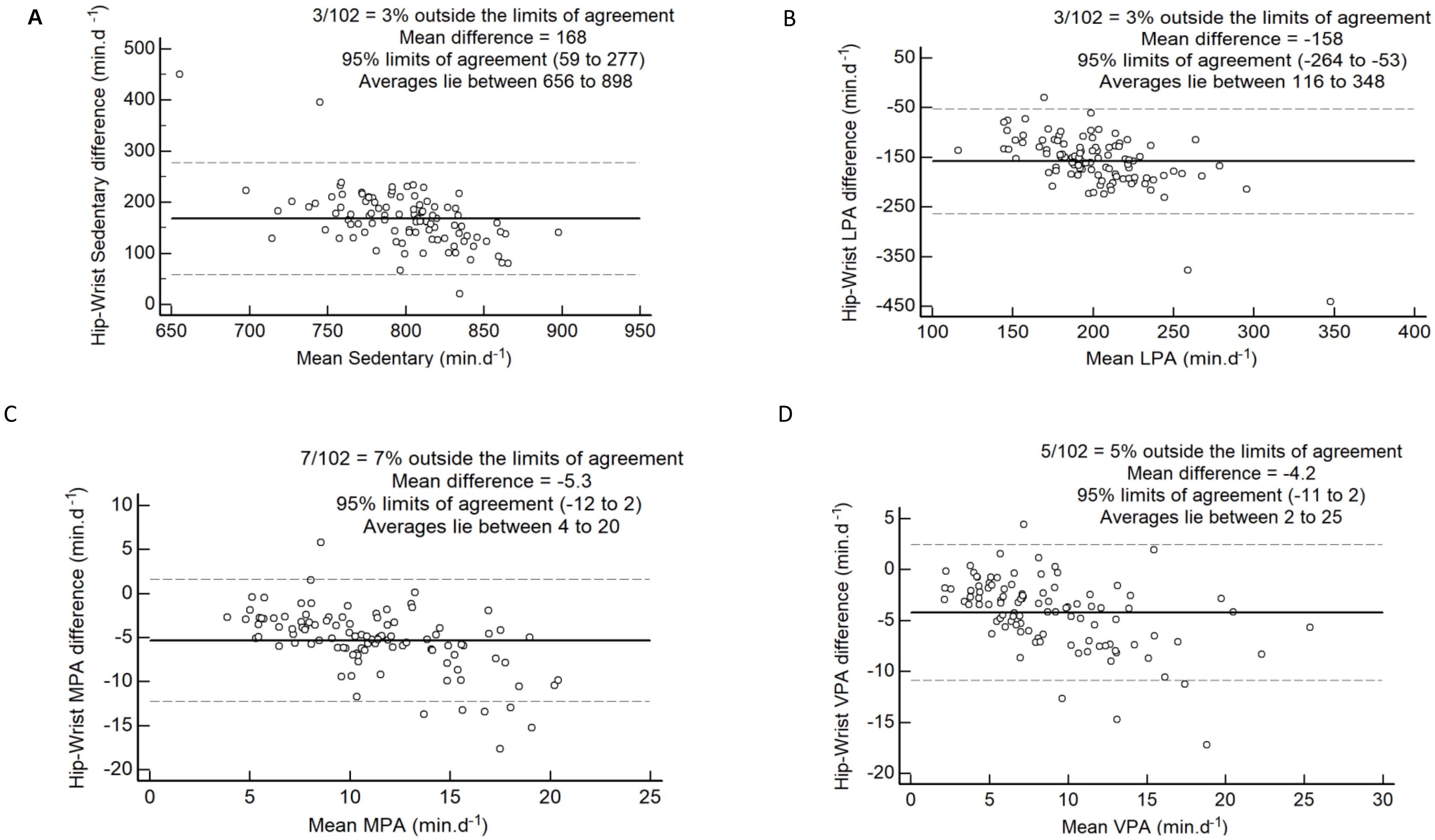
No. Hrs Per/Day	8-Hours			9-Hours			10-Hours		
No. Days	**3 Days**	**4 Days**	**3 Days + 1 Weekend Day**	**3 Days**	**4 Days**	**3 Days + 1 Weekend Day**	**3 Days**	**4 Days**	**3 Days + 1 Weekend Day**
Hip (n=160)	15.2 (14.3-16.1)	15.4 (14.5-16.3)	16.6 (15.6-17.5)	15.6 (14.8-16.5)	15.7 (14.9-16.6)	16.8 (15.8-17.7)	15.9 (15-16.7)	15.9 (15.1-16.8)	16.8 (15.8-17.7)
Wrist (n=160)	15.6 (14.7-16.5)	16.0 (15.1-16.8)	17.3 (16.3-18.3)	16.0 (15.1-16.8)	16.2 (15.4-17.1)	17.4 (16.4-18.3)	16.3 (15.4-17.2)	16.4 (15.5-17.2)	17.4 (16.4-18.3)
P	*0.02*	*0.045*	*0.027*	*0.04*	*0.046*	*0.037*	*0.025*	*0.043*	*0.037*

Wear time ($h.d^{-1}$) are presented as mean (95% Confidence Intervals).

Table 3 Comparisons of adjusted time spent in sedentary behaviour and physical activity intensities.

	SB (min.d^{-1})	**LPA (min.d^{-1})**	**MPA (min.d^{-1})**	**VPA (min.d^{-1})**	**MVPA (min.d^{-1})**
Hip (n=102)	882.6 (876 – 889)	122.4 (117 – 128)	8.5 (8 – 9)	6.8 (6 – 8)	15.4 (14 – 17)
Wrist (n=102)	714.8 (703 – 726)	280.9 (270 – 292)	13.8 (13 – 15)	11.0 (10 – 12)	25.9 (24 – 28)
P	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*

Data are presented as mean (95%CI)



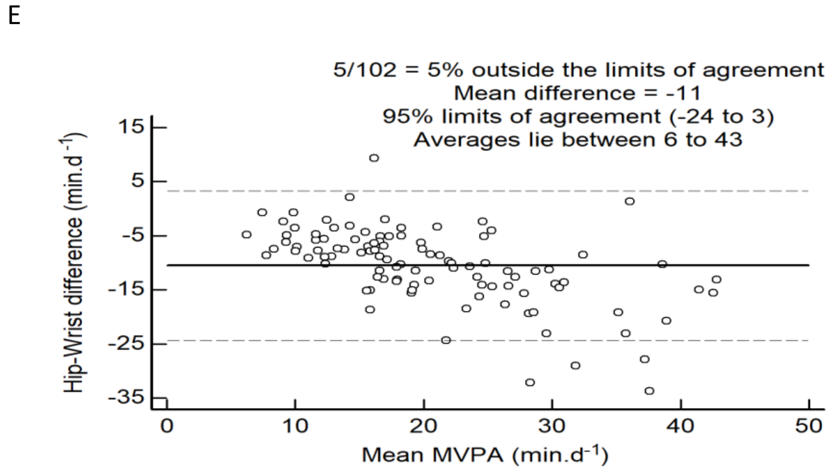


Figure 1: Bland-Altman plots displaying agreement between hip- and wrist-derived SB (A), LPA (B), MPA (C), VPA (D) and MVPA (E). The observed negative bias observed (B-E) indicate that wrist-derived values are higher than hip-derived values. Horizontal lines represent mean bias and 95% limits of agreement